The Workshop Summary Report

Neil Sampson, Workshop Facilitator, the Sampson Group
Greg Gollberg, Conference Coordinator, University of Idaho

OVERVIEW

The Joint Fire Science Conference and Workshop, ***Crossing the Millennium: Integrating Spatial Technologies and Ecological Principles for a New Age in Fire Management***, was held in Boise, Idaho on June 15 to 17, 1999. Support and sponsorship was provided by the USDA Forest Service, Bureau of Land Management, National Aeronautics and Space Administration, US Geological Survey, National Park Service, US Fish and Wildlife Service, Bureau of Indian Affairs, International Association of Wildland Fire and the University of Idaho.

In attendance during the conference were 239 researchers, managers, students, and vendors. Fourteen percent were from outside the United States. Attendants came from Australia, Brazil, Canada, Germany, Italy, Portugal, Russia, Senegal, Spain, Switzerland, and the United Kingdom. Commercial vendors included Country Survey Supply, ERDAS, Inc., ESRI, Inc., Forest Technology Systems, Ltd., Pacific Meridian Resources, and Wagner Fire Suppression, Inc.

The three day event was designed to provide the Joint Fire Science Program with a state-of-the-art assessment of the technical tools available to fire and land managers who need up-to-date spatial information about vegetative and fuel conditions to develop strategies, set priorities, and administer effective fuel management programs. Those needs extend from national level program planning to the local project planning and design level. On June 17, 1999, following two days of invited, contributed, and poster paper presentations, conference attendees were encourage to stay and participate in an all day workshop. Over 100 conference attendees participated in a facilitated discussion led by Neil Sampson, a private consultant (The Sampson Group). They addressed the results of the conference, and provided ideas for future research and development to accelerate the creation, implementation, and dissemination of new technologies to provide fire and land managers at all levels with the latest and best information and decision tools.

WORKSHOP SYNOPSIS

The workshop began with the workshop facilitator, Neil Sampson, summarizing 17 invited papers presented on the opening day of the conference. These papers provided a state-of-the-science overview of pre-selected topics including Overview (3 papers), GIS and Remote Sensing Technologies (4 papers), Mapping (3 papers), Modeling (4 papers), and Treatments (3 papers). On the second day of the conference contributed papers were presented in four concurrent sessions, named GIS and Remote Sensing Technologies, Mapping, Modeling, and two half day sessions, Treatments and Hazard & Risk. Session chairs were responsible for coordinating sessions, introducing speakers, and timekeeping. The session chairs were:

GIS and Remote Sensing Technologies Session
Donald R. Cahoon, Jr., Atmospheric Sciences Division, NASA Langley Research Center USA

Susan G. Conard, Vegetation Management and Protection Research, USDA Forest Service USA

Mapping Session
Tom Bobbe, Remote Sensing Applications Center, USDA Forest Service USA

Thomas R. Loveland, EROS Data Center, US Geological Survey USA

Modeling Session
Robert E. Keane, Intermountain Fire Sciences Lab, USDA Forest Service USA

Elizabeth D. Reinhardt, Intermountain Fire Sciences Lab, USDA Forest Service USA

Treatments Session
Kevin C. Ryan, Conference Co-Chair, Intermountain Fire Sciences Lab, USDA Forest Service USA

Hermínio S. Botelho, Universidade de Trás-os-Montes e Alto Douro Portugal

Hazard and Risk Session

Alan E. Harvey, Rocky Mountain Research Station, USDA Forest Service USA

Philip V. Range, Bureau of Land Management, National Interagency Fire Center USA

Leon Neuenschwander, Professor of Forest Resources, University of Idaho, USA

Following the invited paper summary, session chairs presented their summaries of the contributed papers. Neil Sampson led the workshop attendees in a facilitated discussion that captured the comments and concerns of the workshop attendees with regard to the information presented at the conference, conditions in the field, and future needs. An open discussion brought out a variety of comments and proposals for the Joint Fire Science Program managers to consider. The entire workshop was videotaped, audio taped (on cassette), and recorders took notes. All of this material was collated after the workshop and used to create the document that follows.

NEIL SAMPSON: SUMMARY OF INVITED PAPERS

- The situations facing land managers, and the challenges to both fire and land management that resulted in the creation of the Joint Fire Science Program, create an urgent need for better information, improved risk analysis techniques, and better ways of setting priorities at all levels. As one example, the Forest Service plans to increase its prescribed fire program so that by 2001 they are burning 5 to 6 times as much as they did in 1995, and the challenge of deciding where and how to target these efforts is a high priority need.

- A national land cover characterization program is under way within the US Geological Survey, with plans to produce new information on a 10-year cycle. Collaborative efforts to utilize this information as well as additional information from new remote sensing technologies to create a national fuels data base should be initiated. Those efforts should be instructed by past national mapping efforts, including attention to development of a scientifically sound, comprehensive classification scheme. There has been considerable experience in the land management agencies in the use of remotely sensed information for vegetation classification, and standards and methods are available that can be integrated with a bottoms-up approach to fit local or regional situations. Any data-gathering or mapping exercise needs to be as robust and flexible as possible, since things occur and questions arise at all scales, and there is increasingly diverse use of all natural resource data.

- National fire hazard and risk characterization and mapping efforts are under way at the national, provincial, and state level, in Canada and the United States as well as several European countries. In general, these efforts are in the developing stages, with a variety of initial products. They are being made increasingly necessary and important by issues raised in the UN Framework Convention on Climate Change, which has challenged national governments to improve their monitoring, assessment, and reporting of carbon sources and sinks. Wildland fire and fire management are important contributors to carbon fluxes, and national and international mapping efforts will be needed to support monitoring and verification. Another important use is to identify and prioritize areas for fuel management and treatment priorities. A form of "triage" is suggested as one way to develop these priority rankings.

- Classifying and mapping fuel characteristics is a complex operation, since fuels present a diverse, three-dimensional continuum across the landscape that resists easy portrayal by 2-dimensional polygons on a map. Remotely sensed data interpretations need a significant amount of field-gathered reference data to provide the necessary attributes for fire behavior and effects modeling. The old standard thirteen fuel models developed for use with the fire behavior models are not adequate for many modern modeling and mapping efforts. Development of a new fuel characteristics classification scheme is under way, and should be available for distribution and use in the future.

- A significant amount of research has broadened the understanding of fire regimes, both historical and current, which provides a useful tool in communicating fire concepts and integrating them into land management at a variety of scales, both spatial and temporal. Our current knowledge of some fire regimes is better than others and extrapolating information from point-data sources up to landscape or regional estimates may be the source of considerable uncertainty or error. The better we can understand the nature of fire regimes, and how they are affected by climate, the more well-positioned we will be to assess future management options or climate

change impacts, which may produce conditions unlike any in the available historical record.

- The widespread availability and ease-of-use of modern computers and software has dramatically improved the ability to integrate large-area data sets and produce interpretive maps at a variety of scales. However, accuracy of such maps may be far less than the visual portrayal may indicate. In addition to questions of data accuracy, one must understand the algorithms utilized by commercial mapping and analytic software, because methods useful for some measurements and calculations may be ill suited for others. Scientists and researchers developing models and maps should test the accuracy of their commercial software packages along with conducting accuracy tests on all aspects of the mapping exercise. Maps should be presented with an accuracy assessment so that users are aware of the degree of accuracy really represented.

- In the past, fire and post-fire monitoring and data gathering has been limited by both time and technology. As a result, good data on severity patterns and fire effects within the boundaries of historical fires is lacking. Some of the technological problems, such as remote sensing instruments that were "peaked out" by heat or light intensity have been overcome, and new maps showing intensity and severity gradients within a fire should become increasingly available for study and input into effects modeling. Additional priority will be needed on post-fire monitoring since this activity often suffers from time and money constraints.

- Fire behavior and effects modeling has produced many useful tools, both in terms of increasingly sophisticated computer models as well as low-tech field tools that can be effectively used by land managers. The current models are deeply rooted in fire behavior and management, and may in some instances lack ecological and landscape dimensions that are increasingly demanded as part of management decisions. Bridging the current models to be of more value to land managers should be a high priority. In the process, decision tools need to remain as low-tech, simple and user-friendly as possible, while helping managers assess the degree of "fire dosage" needed on the landscape so that treatments can be designed and managed to produce desired ecological outcomes.

- Fuel treatment modeling is made difficult by the complex and stochastic nature of wildland fire, which makes both pro-active and post-event areas into difficult venues for establishing good research projects. Managers need to be able to predict the effects of various fuel treatments in terms of the fire processes that will be changed, as well as the landscape-level impacts of any treatment. Some fuel treatments will be designed to increase variability and achieve desired mosaic patterns. The question will often be how much to treat and in what patterns? There are two approaches that may be taken: 1) Landscape to site — where sites and treatments are identified as a way to achieve landscape goals; and, 2) Site to landscape — where landscape changes are identified as being needed to protect a particular site (e.g. house). Treatment criteria might include maintaining ecological integrity, reducing crown fires, or protecting areas of high social/cultural values.

- In land management situations where the future portends larger, more intense, and more damaging wildland events, there is a strong concern for public health, particularly from smoke. Land managers will need to work with air quality regulators in the development and implementation of new regulations for maintaining air quality, and these may be exceptionally difficult to make compatible with the ecological needs of wildland systems. From a political viewpoint, it is clear that human health concerns will win out over the ecological justification for management-ignited fires. Ironically, the smoke from the resulting large fires may prove to be the greater health concern.

SUMMARIES OF CONTRIBUTED PAPERS FROM THE CONCURRENT SESSIONS

The following Session Chairs presented summaries from each concurrent session.

- Donald R. Cahoon, Jr., Atmospheric Sciences Division, NASA Langley Research Center for the GIS and Remote Sensing Technologies Session

- Thomas R. Loveland, EROS Data Center, US Geological Survey for the Mapping Session

- Robert E. Keane, Intermountain Fire Sciences Lab, USDA Forest Service for the Modeling Session

- Kevin C. Ryan, Conference Co-Chair, Intermountain Fire Sciences Lab, USDA Forest Service for the Treatments Session

- Philip V. Range, Bureau of Land Management, National Interagency Fire Center; Alan E. Harvey, Rocky Mountain Research Station, USDA Forest Service; and Leon Neuenschwander, Conference Co-Chair, Professor of Forest Resources, University of Idaho for the Hazard and Risk Session

Highlights from each of their summaries follows.

Donald R. Cahoon, Jr.: ***GIS and Remote Sensing Technologies Session***

- GIS has become a fundamental tool for land management, and there are increasingly useful applications being developed and published. The power of GIS lies largely in its ability to integrate many different types of data, and develop comparative analyses.

- In order to improve GIS mapping, more consistent and well-portrayed accuracy assessments are required.

- Aircraft remote sensing and aerial surveillance of fires are producing near-real-time products that can be useful in managing a fire event. A current challenge is to integrate geo-referencing into the fire mapping in near real time.

- Satellite remote sensing is still dominated by passive sensing methods, and there needs to be more focus on addressing critical management issues. Active sensing (SAR) is still in its infancy, but it shows encouraging results that may have potential in mapping fuels. Image noise is a problem with any form of remote sensing that complicates analysis.

- There is a lack of national-level focus in remote sensing programs. Such focus is needed to answer important questions relating to fuels, such as:

    - What fuels are of most concern and how are they spatially distributed?
    - How much fuel burns during a fire?
      How does management affect fuels and fires?

- Remote sensing products are needed for mapping burned areas on the national level, developing a fire severity product, and integrating fire experience with fuel conditions. Development of a national spatial database that includes burned areas, active fires, and high-risk areas is badly needed, and the United States is lagging much of the world in this regard.

Thomas R. Loveland: ***Mapping Session***

- This session focused on mapping fire patterns, fuels, fire detection, and a suite of other environmental variables. Also covered were time elements, historical perspective, contemporary issues, baseline conditions, and predictive mapping into the future. There was a strong emphasis on emerging technologies.

- Mapping is the process of reconciling errors. It is an exercise in placing things in spatial context that focuses on the importance of geography. Place means potential, and good mapping enables comparisons while it facilitates understanding of cause and effect of activities. The comparative framework cannot be overstated. Emphasis should be placed on long term data management and archiving. Only by doing this can we see the impacts of management practices and of ecological processes.

- The best strategies for improving mapping include the encouragement of innovation while retaining useful traditional tools. Mapping and modeling are joined activities, and one cannot progress without the other. Remote sensing is a primary tool for modern mapping, but it has limitations that must be recognized and incrementally overcome and improved.

- Accuracy and accuracy assessment are and will continue to be challenging. The transition between different scales is a common problem. Accuracy appears to be on the rise in things thematic (fuel mapping), but other papers looking at historical perspectives, quantitative measures, biophysical parameterization failed to address the issue. An issue that needs to be collectively discussed is what is acceptable accuracy? It probably depends on the application. A number does not mean anything until it is interpreted in context. We need to determine what standards we can live with.

- Further discussions are needed on sampling strategies in order to map process, moving beyond sampling homogeneous elements and into sampling along gradients. New instruments such as those concerned with hyperspectral data are worth watching closely. Although it is currently in the experimental stage, it may become the wave of the future.

- It is worth remembering that mapped data are multipurpose. They are valuable for fire science, land management, environmental assessment, general scientific research, and public relations.

- Finally, fuel mapping is an international issue. The global change and fire research communities are joined at the hip. We need to foster collaboration between them.

Robert E. Keane: *Modeling Session*

- A diverse cross section of models was presented. Model categories included fire behavior, fire danger, fire condition, fire effects, smoke, and a suite of ecosystem dynamics models that predict vegetation succession, erosion, and tree mortality. In addition, models were presented that were developed to either derive input into fire behavior models, or to run on their own, such as some of the weather and fuel models.

- Every model presented was based on fundamental first and second order fire effects research. In order to improve current models and create new ones such research must continue.

- The resolution of the model variables should match the resolution of the simulated spatial and temporal domain and the resolution of the spatial and temporal domain should exactly match the questions that the model is being used to answer.

- We need to support interaction between models. There needs to be consistent, compatible formats for input and output data between models. Work is also needed to promote interactions between different types of models, such as climate, fire, vegetation, air transport, and soil erosion. Again, this will be facilitated by development of standard input-output formats.

- Not all models need to be complex or spatially explicit. It may be possible and desirable to develop simpler models from complex models and also to use the complex models as pseudo validation of the simpler models for some special cases.

- Since managers have diverse questions there needs to be a diversity of models to answer these questions. It is unlikely that there will ever be a mega-model that will answer all the questions for any given purpose. As such, model diversity should be promoted. Managers should not be told which models to use, but modelers should provide them with a set of guidelines or a key on what situations are most appropriate for which models (where and when).

- Because the models are becoming more complex, managers need more help using them and interpreting their results. New methods of technology transfer and training need to be explored. Managers also need better access to models. Widespread documentation and publication of models is needed and there needs to be active comparison of models in a Web environment. Adequate funding for model documentation should accompany model development.

- Models should be peer-reviewed and adequately tested prior to widespread distribution. Model comparisons should have a larger purpose than they currently have. They should be used to quantify variability in systems, identify limitations and advantages of each model, improve and refine models, and help develop a key to give management that would identify which models are appropriate when and where. Perhaps, a model comparison environment should be created where modelers are encouraged to post test landscapes on the Web that contains the data needed to run their models.

Kevin C. Ryan: *Treatments Session*

- No common theme emerged from the 11 papers presented in the Treatments Session.

- Fuel treatments are very difficult to implement and test experimentally. In homogeneous areas identifying a control is problematic. The treatment dosage is difficult to measure. Some of these difficulties may be overcome through tools developed in the other sessions, i.e., remote sensing and modeling;

however, such tools were not discussed in this session.

- It is also difficult to identify response variables. Consensus is lacking on what variables to measure, and how to measure them to determine whether or not a treatment had a positive, negative, or neutral effect.

- One paper proposed a national fuels treatment system where a series of sites across the country would have standardized treatments and protocols for measuring response variables.

- Other papers used modeling to help determine how fire behavior changes as you move between areas of low and high fire potential.

- A few papers addressed issues and concerns, such as how to take advantage of models that predict El Nino, or other climatological models; issues of coordinating funding during optimal times to conduct treatments; of broadening our view of what fuels are; of the importance of not extrapolating results too far across the landscape; and that if we expect to maintain certain vegetation types, we need to consider much larger landscape scale treatments.

- Another paper outlined the European Commission's funded project to develop a full decision support system for fuels treatment in Europe. Such an approach should be considered in the U. S.

- In summary, designing treatments involves social as well as biological parameters, and must consider broad management goals at the landscape scale as well as at the project scale.

Philip V. Range, Alan E. Harvey, and Leon F. Neuenschwander: *Hazard and Risk Session*

- There were 10 papers presented that described a variety of GIS models.

- Models were all used to highlight or prioritize areas of high risk. Almost everyone uses a relative ranking of some kind (high, medium, or low for example). These ranking systems are useful in describing the relative fire risk, where fires are located, and the resources needed to address the risk.

- Models seemed to be very useful for communication within the units, along the bureaucratic agency lines, and with the public and policymakers. One paper suggested that the models could be used for program evaluation and accountability.

- A problem that emerged concerns the definition of risk. Almost every paper used it differently. It was equated with occurrence; with a combination of hazard and occurrence; another used occurrence and damage or potential damage; still another used occurrence, fire behavior, and fire effects; and one paper used the crown fire models to develop the hazard and risk profile.

- Most data input into these models was remote sensed. There was not any commonality in the GIS methodology. Scale or accuracy was not described in any of these models.

- In some cases it appears we are basing hazard and risk on some fairly shallow capabilities of vegetation classification systems.

- We did not discuss ecosystems at risk or keystone species, or genetic resources.

- Although many efforts are being carried out at the landscape and state levels, a national database containing consistent data layers with standards for scale and accuracy is needed.

EXCERPTS FROM THE FACILITATED DISCUSSION

After reviewing the recorders notes, videocassette, and audiocassette comments were analyzed for content, abbreviated where possible, and were grouped according to common themes. There were 84 comments taken and from them 8 themes or categories were identified. They are as follows:

Communication and Training (21)
Data Requirements (4)
Fuel Mapping (13)
General Comments (12)
International Perspective (6)
Issues of Scale (6)
Management Issues (10)
Tools Development (12)

The "General Comments" category contained those comments that did not fit into any of the seven other categories. The total number of comments per category is in parenthesis. The following excerpts by category indicate the types of comments that were raised by the workshop attendees.

Excerpts from Communication and Training:

- There needs to be, "other forums where managers can compare notes regarding models they use…"
- The "states need to know who, when and where people are burning so we can coordinate with our neighbors…"
- Consider the "military model of focused and deliberate dissemination of information…"
- "Managers and researchers need to work together on tool development."
- "…I don't know where to draw the line between where I should stop developing new knowledge and hand this stuff off…"
- "Need to catalog GIS data and make it readily available so people are not always reinventing the wheel."
- "Need to develop consistent terminology."
- "Research and results need to be made available as quickly as possible on the Internet."
- With regard to developing models and systems, "…don't forget the public."
- "Those of us working in GIS for land management agencies are struggling to keep our heads above water, let alone keep up with the rapid changes in our field. There is minimal if any money for our training."
- "The vast majority of GIS specialists have minimal if any real knowledge or expertise with remote sensing."
- "I did want to point out that in the private sector we tend to see a lot of different agencies that are not talking to each other. There are a lot of coverages that I don't think people realize exist."

Excerpts from Data Requirements:

- We "… need more data for smoke management. States need data to be compliant with EPA…"
- "It doesn't surprise me at all that there is a clamoring for data to be developed, but that's partly because we've set the stage by developing models that need those data."
- "We have a serious lack of ability to produce accurate input layers for models."
- "… I don't care to see another model. I want to know what we've got and I want to know how we can improve the models that we have. Where I am we do not have any fuels data. We need the inputs."

Excerpts from Fuel Mapping:

- We "… should focus on a ground campaign to characterize the spatial and temporal variability in fuels."
- "The challenge is to implement in a real mapping strategy and encourage some prototype development and implementation."
- "… part of the problem with our ability to produce these layers is the lack of quality data. Accuracy is a serious issue."
- "How do you develop a proper sampling design to map fuels?"
- "Ground referenced data is needed regardless of map scale. We need to spend time gathering this data."
- "We propose that at least 25% of the JFS funding be directed to the acquisition of ground reference data for fuel model mapping."
- "… 12,000 FCC's is really not a very big number, that you can aggregate those any way you want."
- "There's not 12,000 different kinds of fire behavior out there. We've got to come up with a scheme that is simple, we can use to communicate with, and build maps."
- I support "the idea of a national fuels mapping program."

Excerpts from General Comments:

- This "… meeting focused on technology, but need to incorporate technology in an ecological context."
- "I think that maybe we ought to spend some of our attention on fire regimes, where we want to go with fire, what should be the fire landscape that we want to create."
- "Climate has had and continues to have profound effects on vegetation. I think we ought to find out how much of it is our input and how much of it is Mother Nature's."
- "An overarching theme from the conference ought to be what does everybody want from the scientists?"
- What we need is "some way to assess severity that links some of the carbon and nitrogen and ecological factors (such as vegetation change) with things that we might be able to very quickly assess remotely."
- "We should get some standards for when fire severity is mapped."
- We should "…partner with NASA and perhaps locate the regional fire science and applications cen-

ters where there are already NASA centers, the so-called Regional Earth Science Applications Centers (RESAC)."

Excerpts from International Perspective:

- "… should encourage more scientists from less developed countries to attend specialized workshops (like this one)."
- "Developing countries need help training more people with regards to remote sensing technology."
- We "…need to develop consistent terminology."

Excerpts from Issues of Scale:

- "When building models that are to work across several scales it should be remembered that the average output of a nonlinear process cannot be obtained by taking the averages of the input."
- "… there needs to be scale integration at the national level."
- I recommend "… the establishment of regional fire science research and applications centers to address issues of scale, space, and fuel variability."
- "We need severity at two different scales, coarse and fine scale."

Excerpts from Management Issues:

- "Managers want alternatives and they want a consequence for each one."
- "… the health and integrity of grasslands and shrublands make the forest health problems and tractability pale by comparison."
- We "… should have an inventory of the land managers needs where we define the spatial and temporal resolution with which these displays of future alternatives are going to be useful…"
- We "need help monitoring fire effects … in order to show the public and to build credibility."
- "The Europeans are ahead of us in some areas apparently because they are working together on a multi national basis. We have the administrative structure, but we are not working together."
- "If models are too complicated those in Congress will not understand and will throw them out."

Excerpts from Tools Development:

- "There are 3 components to tool development that should support one another. They are research, management actions, and landscape characterization."
- I think we "… need to do an integrated assessment of the whole problem, bringing expertise from all the different areas."
- "Please keep field managers in mind when models are developed. They are the ones that are either going to be using them or interpreting their results."
- Maybe "… rather than being overly concerned with model validation we should consider what different decision would have been made if you had not used that tool."
- I "support a summary of different models and other tools and list their limitations and appropriate uses."
- "I really like the concept of linking all these models, from climate to vegetation, to hydrology… and I'd like to add air quality to that."

SYNTHESIS AND SUMMARY OF THE WORKSHOP

The following comments are based upon a thorough review of the invited and contributed paper summaries, and workshop attendee comments from recorder's notes, videocassette, and audiocassette. A general conclusion from the conference is that an enormous amount of work in the past was done to develop fire-related data and models. Much of this work was deeply rooted in fire behavior research and was driven by management concerns at the incident or project level. A variety of different models to assess behavior and fire effects are currently utilized, and some have been in widespread use for years, having developed a broad and capable user base among land and fire managers. However, current issues associated with the use of these models includes a general absence of specific fuels or vegetative data at the administrative unit, incompatibility in the input and output data that limits the ability to move information from one model to another, and an ongoing need to train field personnel in model use. Despite these problems the models provide significant value to fire and land managers, and provide a solid foundation for the decision tools of 21st Century.

Far less available are landscape-level tools needed for large-area assessments and the data sets and risk characterizations needed for state- and national-level strategic planning and priority setting. Another identified gap is the range in system variability contained in current models. Even though many are designed to predict fire behavior or effects well beyond the range of past experience, many current fire events are generating such extreme behavior that current model limits are exceeded. With fire experts predicting that future fires may continue to demonstrate even more extreme behavior and fire effects, it was concluded that efforts to extend the range of variability in current models were needed.

In general, the creation and widespread adoption of models has created an enormous demand for more and better data sets at a variety of scales. A significant portion of the data gathering effort should focus on ground reference data to provide improved validation and accuracy assessment of remote-sensed or derived data. Data sets, to be most useful, should be consistent on a nationwide basis, accessible through the Internet, and have metadata files, accuracy assessment, and utilization guidelines. Utilization guidelines would be useful in helping prospective users better understand and appropriately apply the data based on resolution, scale, and scope. Particularly in the case of ground reference data, there needs to be more coordination and participation in generating data. This is going to require a strong and continuing institutional commitment in recognition of the importance of a high-quality national data set.

A basic concern in modern land management is sustainability. Databases and decision tools related to fire and fuels should be relevant to the criteria and indicators that land managers utilize to assess the impact of any activity on sustainability. An important management consideration is to be able to evaluate and continue to monitor fire's role in succession and the impact that different fire effects have upon the likelihood of achieving desired future conditions. An integrative approach or decision support "what-if" tool that considers ecological and social factors would be very useful to managers.

In supporting fuels research, data development, and data systems, a high priority should be given to integrated assessments that are based upon, and designed to develop, holistic approaches involving managers, field personnel, GIS personnel, and research scientists. It is also important to assure the inclusion of all wildland ecosystems in reference data, data sets, and models. Much of the Nation's wildland is not forested, and understanding fuel characteristics, fire effects, and management implications on all ecosystems is needed.

There is an urgent need to link fuel and other physical conditions (such as soils) to models of potential fire severity, and to improve post-fire severity assessment and mapping. This should go well beyond vegetative mortality where possible, in particular focusing on soil change that may be linked to second-order fire effects such as hydrophobicity, erosion, loss of system nutrients, reduced productivity, or significant change in successional pathways. Research to develop standard field techniques and measures for post-fire severity assessment may be needed. Greater consistency in these assessments is needed to help construct a national data set. There was some discussion indicating that immediate monitoring (perhaps measures of post-fire heat flux from soils) may produce one layer of useful information while delayed monitoring (perhaps of crown mortality) may produce better indicators of vegetative impact.

There is also a need to focus on the concepts of Hazard and Risk, as well as Severity, and to encourage more consistency in the use of the terminology and develop more widely recognized protocols and processes for making and communicating these interpretations. Since these are not physical terms, but indicators, it is important to clearly communicate the values that were used to develop relative indices. Identifying and prioritizing relative hazards and risks on a national scale, as part of a national assessment, would provide both a useful tool for national decision making and an opportunity to promote consistent application of these concepts at state and local levels.

Data sets, maps, and models are of minimal value unless people can readily find them, adapt them to their immediate needs, and use them to help solve a relevant problem. Land managers have limited time, money, and patience to allot to learning new methods, models, or tools. Their participation as a partner in development of all fuel and fire decision tools is essential. Much of what needs to be done, such as developing reference data sets, observing and mapping fire effects at the event scale, and improved monitoring of post-fire severity is tied to field staff and management activity. If managers know what is needed, consider themselves equal members of a team, and feel that the information developed is worth its cost in terms of helping them solve their management problems, more adequate resources are likely to be allocated to information-gathering.

In addition to partnering with managers, it is important to develop collaborative approaches between agencies, scientific disciplines, the private sector, and the public. Data development and mapping efforts need to include social and economic communities as well as scientific and technical considerations. In the process, both scientists and managers should look for natural allies in nontraditional groups such as youth, conservation organizations, retirees, etc. New communication technologies will proliferate and continue to provide viable tools for improving information sharing between agencies, international groups, private

corporations, politicians, the public, and users. Rather than be feared, these technologies should be embraced, and used to create an open marketplace for ideas, data, and tools that are needed internationally by wildland fire professionals. International standards and protocols for both spatial and non-spatial data should be encouraged, especially with regards to tools development.

New technologies and the tools that are derived from them must be integrated into the fire management program. Proper training, field-testing and application, and communication with research, user, public, media, and political communities are all components of such integration. Communicating results and creating realistic expectations for the products of fuel and fire data, maps, and modeling will be essential in building and maintaining public support for their continued development, application, and maintenance.

SPECIFIC TECHNOLOGY AND TRAINING NEEDS IDENTIFIED

The following technology and training needs were identified also based upon a thorough review of the invited and contributed paper summaries, and workshop attendee comments from recorder's notes, videocassette, and audiocassette.

Specific technology development needs identified included:

- A National Fire and Fuels Data System, available to all users through Internet access, that includes:
  - Standards and protocols for data elements and formats to be used as both inputs and outputs in fuel and fire mapping and modeling
  - A glossary of standard use and definition of terms, units, and concepts
  - Methods, Concepts, and Limitations in scale and scope transitions and hierarchies
  - Methods and protocols for assessing map and model accuracy
  - Methods and standards for gathering reference (ground) data
  - Standards for interpreting and classifying remotely-sensed information
  - A new system of Fuel Characterization Classes, with accompanying attribute data as available
  - A national vegetative cover mapping data set, updated periodically
  - A national fuels mapping data set, updated periodically
  - Other national data sets (such as DEM's and administrative areas) available for incorporation into mapping or modeling efforts.
  - A Catalogue of Fire-Related Models, complete with instructions and capability assessments of each model, with standard versions available for downloading and use
  - A Catalogue of Fire-Related Data Sets (Fuel maps, DEM's, etc.) with meta data, accuracy assessments, and protocols.
  - A Catalogue of digital remote-sensed, geo-referenced images.
- A National Fire and Fuels Development and Training Program, based on:
  - Collaboration between agencies, institutions, and organizations at all levels with a special focus on partnerships between researchers and land managers in the development and implementation of fire and fuel management data and models to achieve a strong focus on decision-relevant outputs;
  - A focus on ecological issues and perspectives to provide managers and interested publics with best available estimates of the ecological outcomes of management options, both short- and long-term as well as local- and landscape-scale. This includes an emphasis on fire effects as related to fire severity, as well as relative assessments and characterizations of risks and hazards.
  - Incorporation of the latest developments in remote sensing, geographic information systems, information management, and communications technologies.
  - An emphasis on encouraging innovation and information-sharing among research scientists and land managers on an international basis, including such factors as open architecture and standards for models and databases; easy communication between researchers, managers, and others via the Internet; and regular professional opportunities for publication, presentation of new technology, and international discourse.

GENERAL RECOMMENDATIONS TO THE JOINT FIRE SCIENCE GOVERNING BOARD AND DIRECTOR

Based upon the information presented during the conference and the workshop that followed we offer the following recommendations to the Joint Fire Science Governing Board and Director.

Recommendation 1:

Management tools including databases, maps, and models should be grounded in ecological research and principles. An emphasis should be placed on landscape level tools that – where appropriate – incorporate biological, biochemical, climatological, ecological, geological, and morphological factors.

Recommendation 2:

A more integrative and systematic national approach to fuel mapping and modeling that sets standards and protocols across multiple spatial and temporal scales and that includes a ground campaign to provide accurate model input data is needed. Within this framework remotely sensed data, GIS technology, and models should be better integrated and documented.

Recommendation 3:

The process of tool use including comparison, selection, acquisition, training, implementation, evaluation, and support needs national administrative focus, guidance, and support.

Recommendation 4:

Technology development, transfer, and communication need to be improved between developers and user communities.

Recommendation 5:

Collaborative approaches to research, development, and implementation of new information and decision support tools need to be encouraged.

Recommendation 6:

More precise and consistent definitions and standards are needed for fire severity, hazard, and risk.

Recommendation 7:

There should be a new emphasis on training that incorporates the latest developments in remote sensing, geographic information systems, information management, and communications technologies